Heaters power sizing and AMS activation sequence

M.Capell; M.Cova; C.Vettore

Why do we need heaters?

1. To keep AMS above survival conditions during transfer from STS to ISS
2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit
3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)

Freezing could take place

- Transfer phase to the ISS
- Power outage during the nominal operating phase
- Cold environment during nominal operation

De-freezing is needed

- Ammonia freezing (in the heat pipes and in the LHP) is not a safety issue.
- But the start-up of a heat pipe from the frozen state may be a problem if heat input is concentrated in small portion of the pipe
  - So we need to de-freeze Zenith radiators before operating LHP (DE-FROST HEATERS on ZENITH RAD) : $T>T_{melting}(NH_3)$
  - We need to de-freeze Tracker radiators before starting operating the Tracker loop (DE-FROST HEATERS on TRACKER RAD/CONDENSER): $T>T_{melting}(CO_2)$ => Q TBC by TTCS detailed analysis

Heater management

- Heaters are controlled thermostatically
- 12 pairs of heaters line are available from PDS
- Heaters can be en/disabled at PDS level to manage the total load to be less than 2KW
  - One of the heater line could be disabled when we decide to turn on the corresponding equipment
- Each of the heater line may even form a “bus” with multiple thermostats/heater circuit
- Individual thermostat status (ON/OFF) unknown

AMS 02 –Thermal Control System Design

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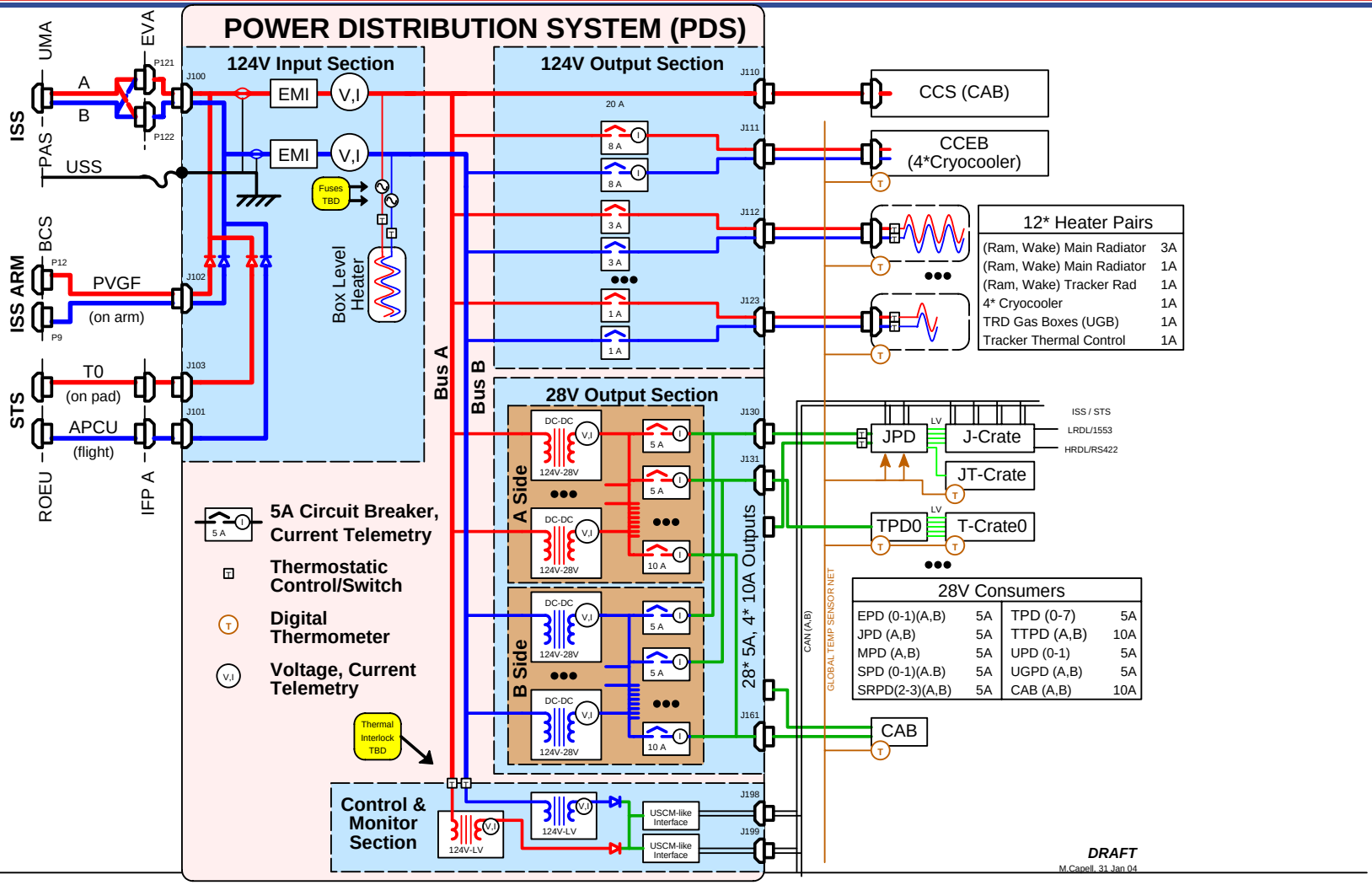
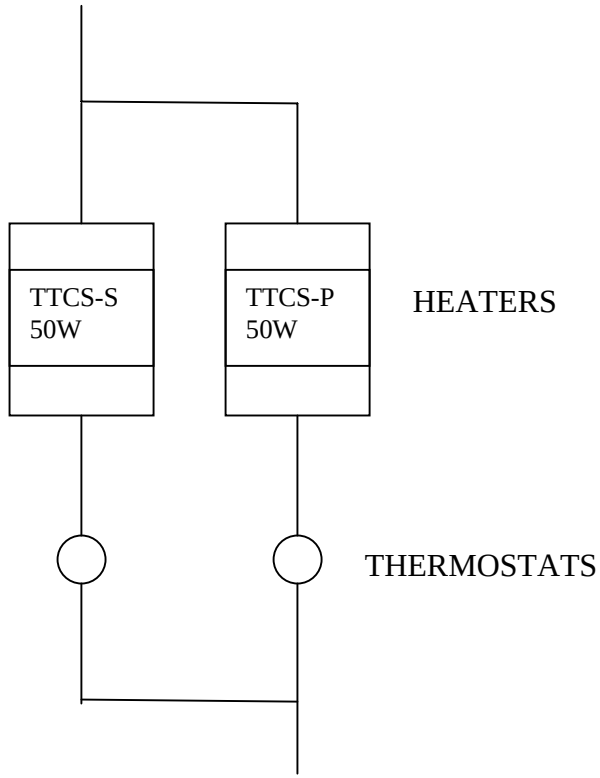


Output lines	Description	Power A side [W]	Power B side [W]
1	Ram Tracker Radiator/Condenser	150	150
2	Ram main radiator	350	350
3	E-crate+Lower HV bricks	10+60	10+60
4	Wake Tracker Radiator/Condenser	150	150
5	Wake main radiator	350	350
6	Zenith radiator (all 4 quarters)	100x4	100x4
7	Cryocoolers	50	50
8	Cryocoolers	50	50
9	Cryocoolers	50	50
10	Cryocoolers	50	50
11	TRD Gas Box+CAB	69+40	69+40
12	TTCB primary and secondary	50x2	50x2
	TOT	**1879**	**1879**

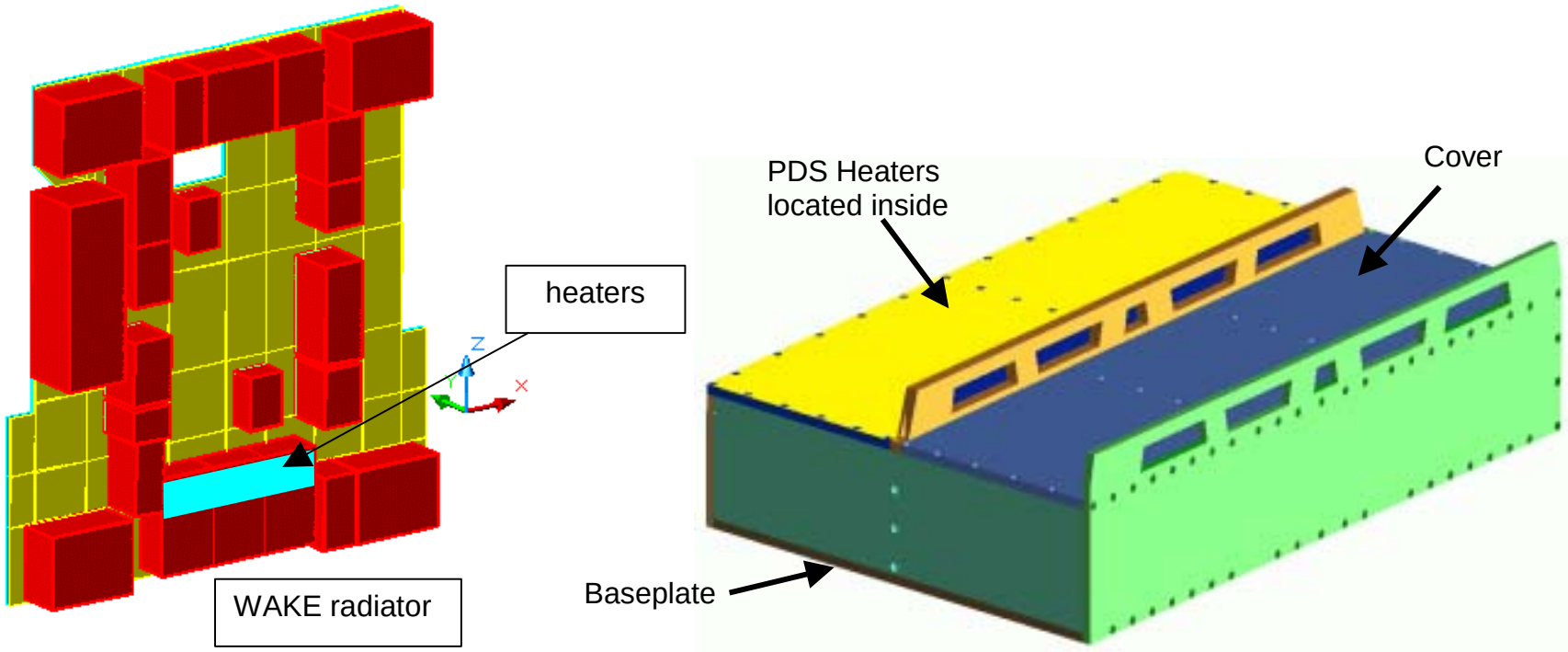
Heater bus arrangement example for TTCB-P and –S boxes



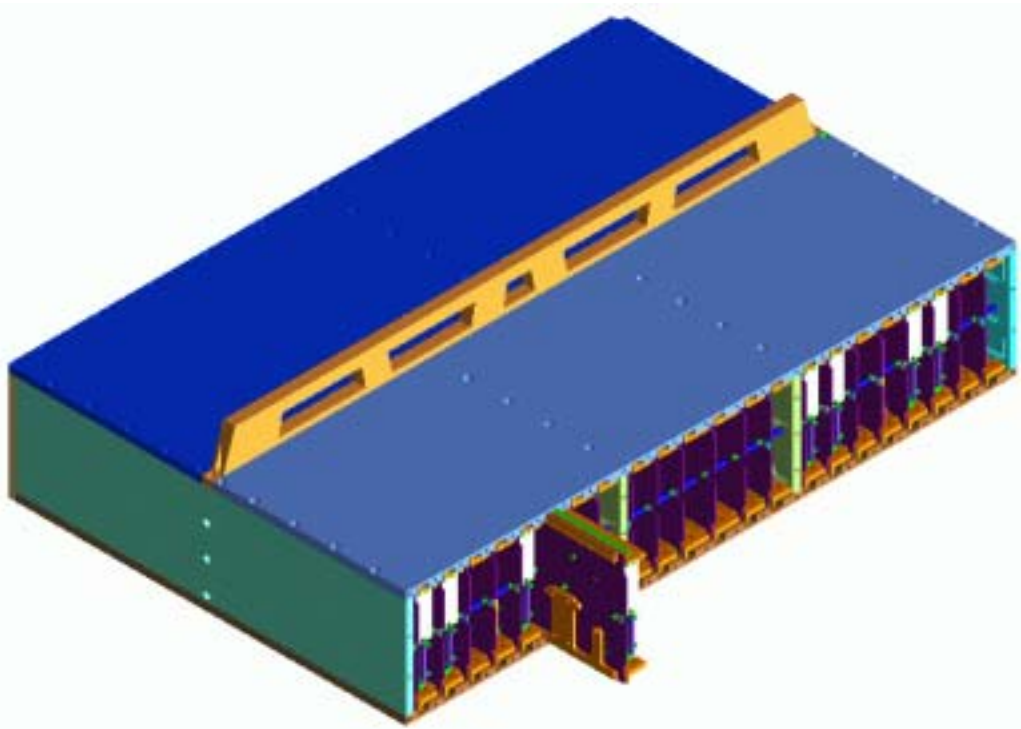
How do we e/disable heaters?

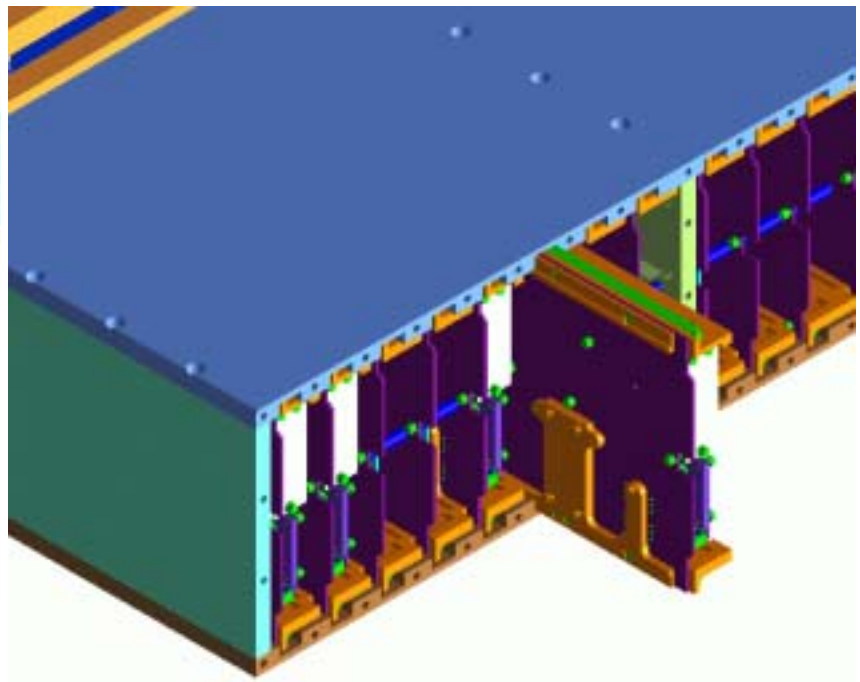
- We can e/disable heaters according to the associated electronics and /or radiator temperature
- We know the temperature of the electronics by means of the GTSN (= Global Temp Sensor Net) based on Dallas Temperature Sensors (DTS) and of the Zenith/Tracker radiators by means of PT100 (or PT1000)
  - DTS readout is done by USCM in J crate
  - Zenith rad. PT100 readout by CCEB
  - Tracker rad. PT100 readout by TT crate

PDS Heaters location 1/3

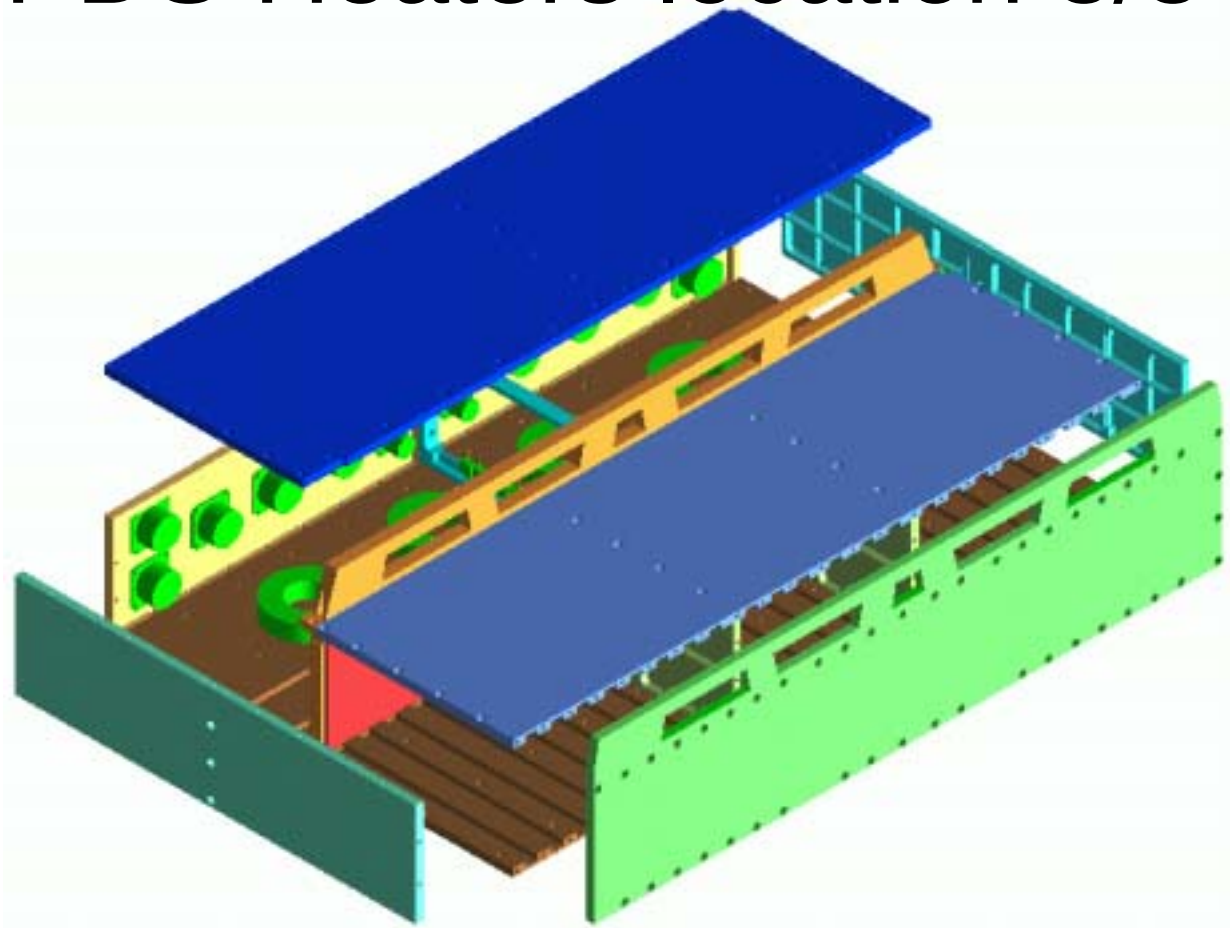


PDS Heaters location 2/3

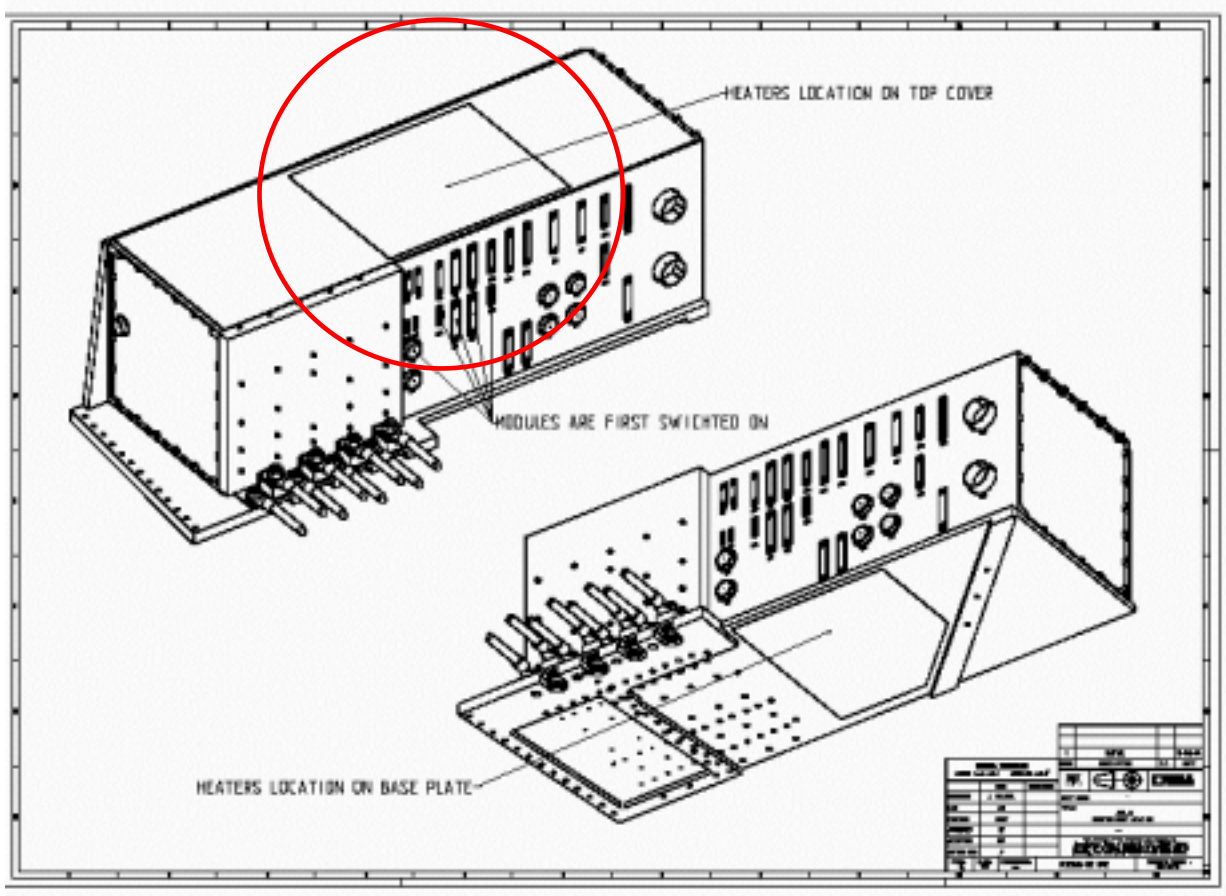




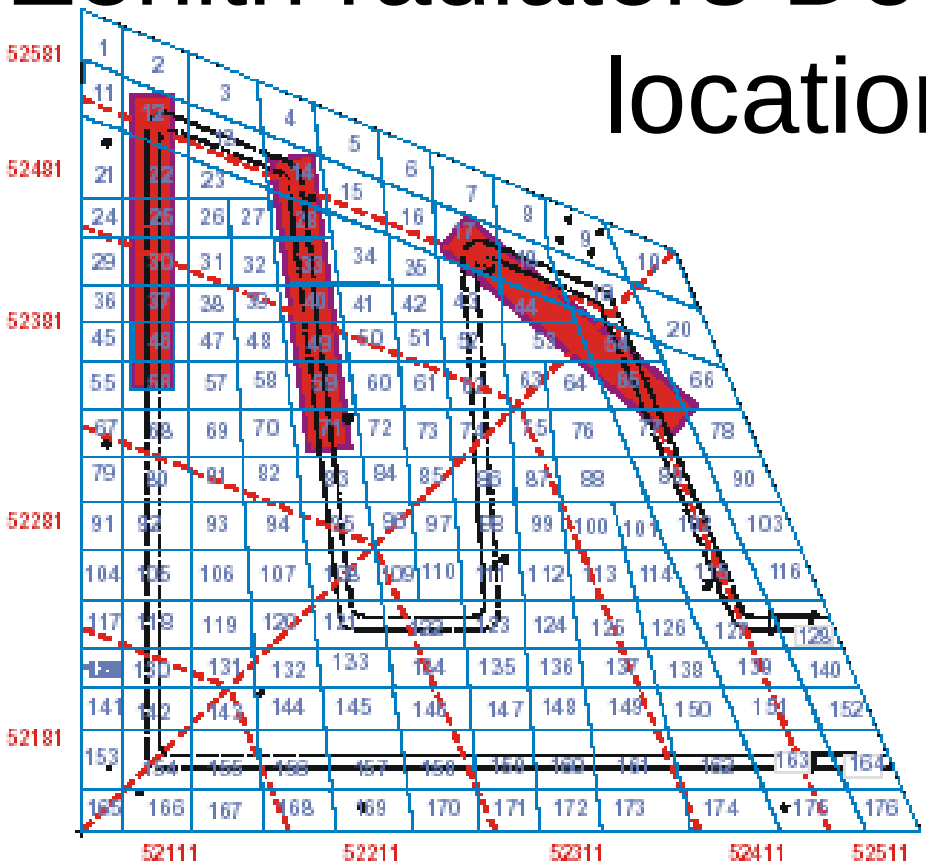
PDS Heaters location 3/3



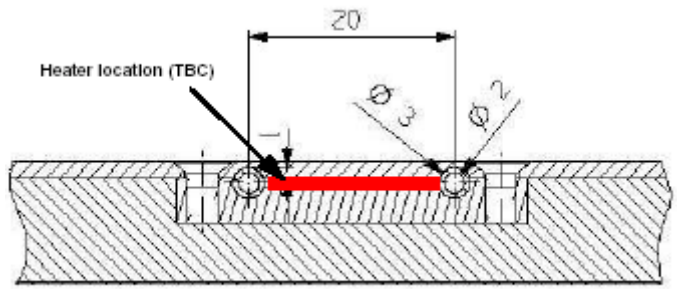
CAB Heaters location



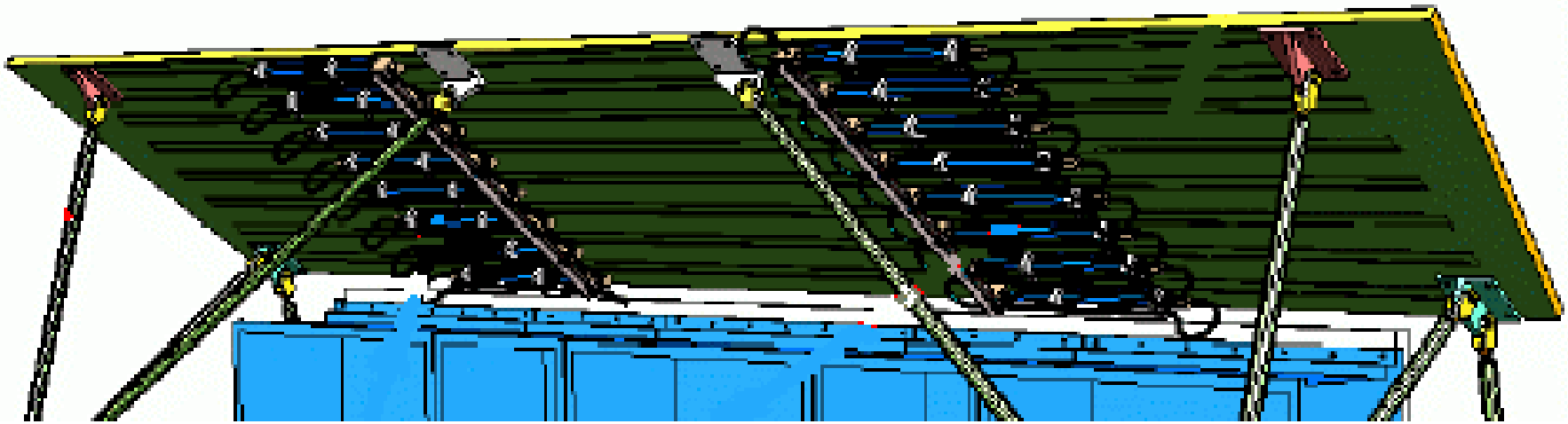
Zenith radiators De-frost Heaters location



OHB PROPOSAL

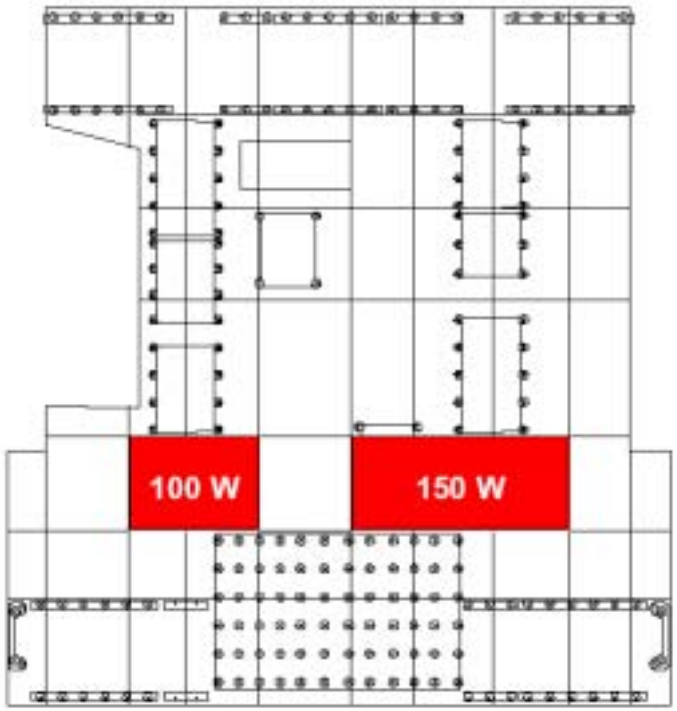


Tracker rad. Heaters location

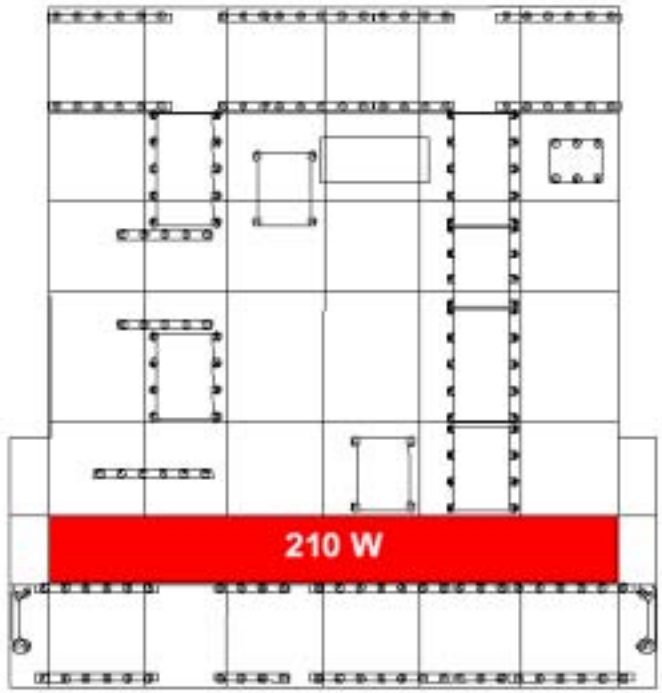


- Heaters on the radiator back (additional heaters on the condensers not needed)

Main rad. Heaters location



RAM



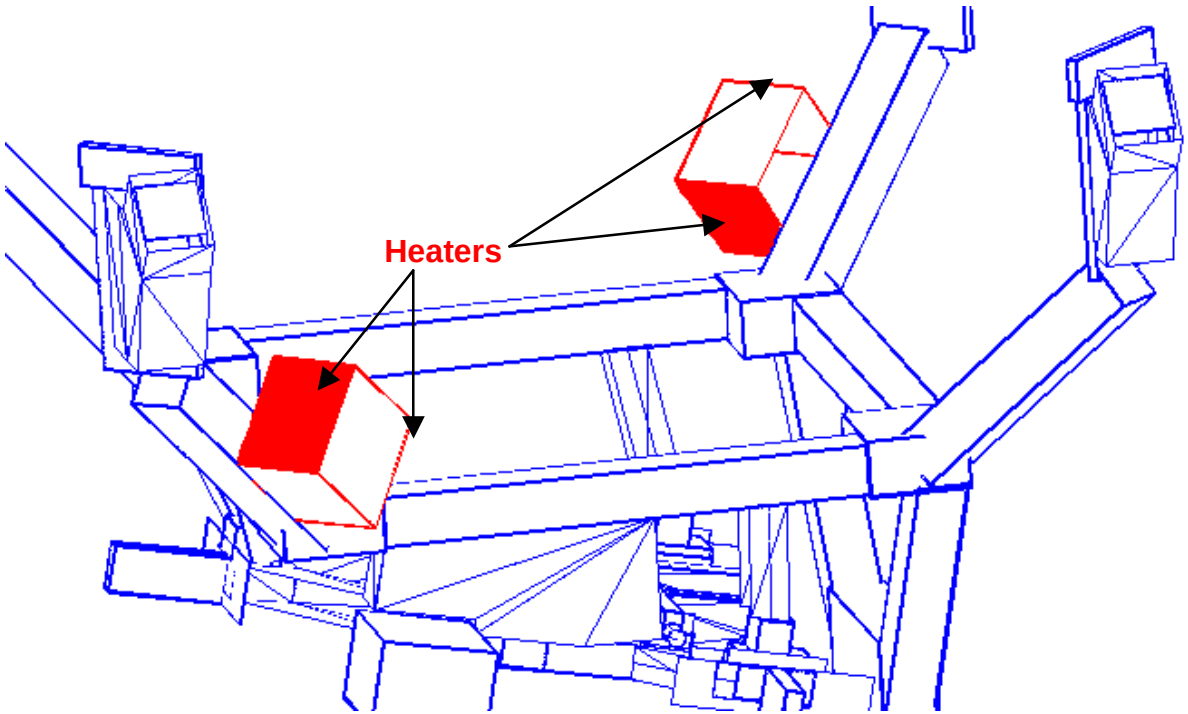
WAKE

From OHB detailed analysis

Remark: The heaters can not be placed underneath the boxes

E-crates Heaters location

- Unlike the boxes on the main radiators heaters are located directly on the E-crate

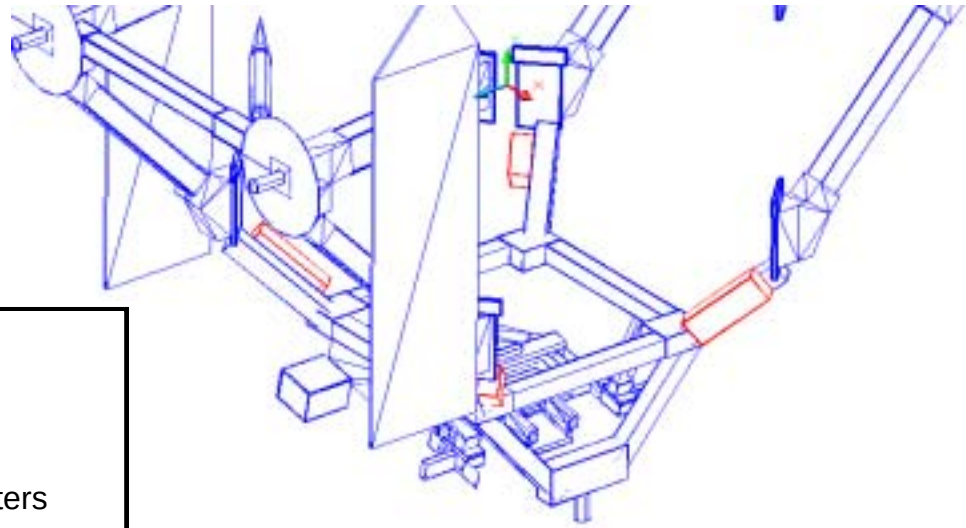


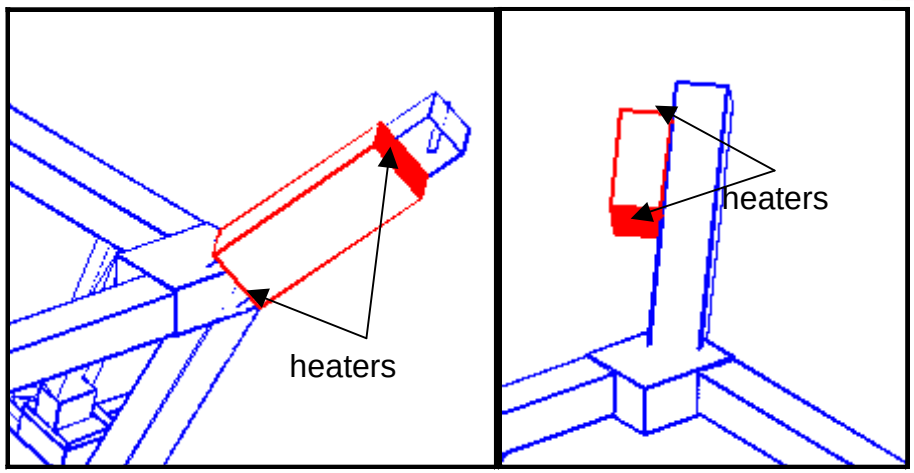
HV bricks

- Ecal and RICH HV bricks heaters location to be defined with dedicated detailed analysis
- First iteration: heaters on outer sides

EHV bricks Heaters location (1st iteration)

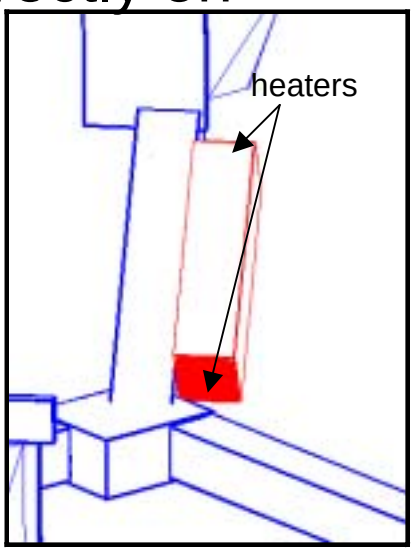
- Unlike the boxes on the main radiators heaters are located directly on the HV bricks.

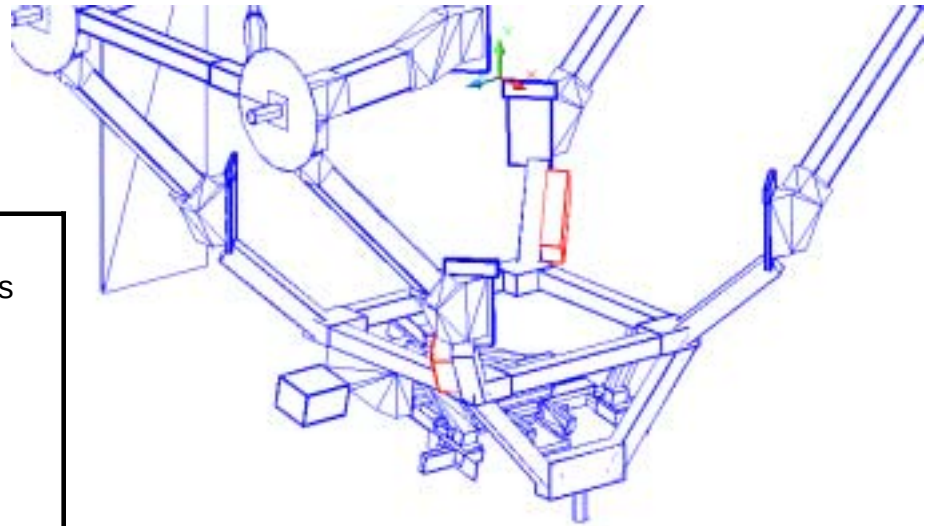




RHV bricks Heaters location (2-0-2-0) 1st iteration

- Unlike the boxes on the main radiators heaters are located directly on the HV bricks.





Cryo body heaters (substitution heaters)

- These heaters are located on the LHP evaporator
- Main functions:
  - Support the nominal cryo-cooler operation in order to avoid freezing on the zenith radiators under extreme cold conditions
  - Start-up the LHP operations and drive the temperature to the CRYO minimum switch-on temperature

Why do we need heaters?

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2. To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit
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AMS/02 transfer preliminary results

1. AMS in the STS docked at the ISS
2. AMS in hand-off position
3. AMS on the ISS truss

Selected Case

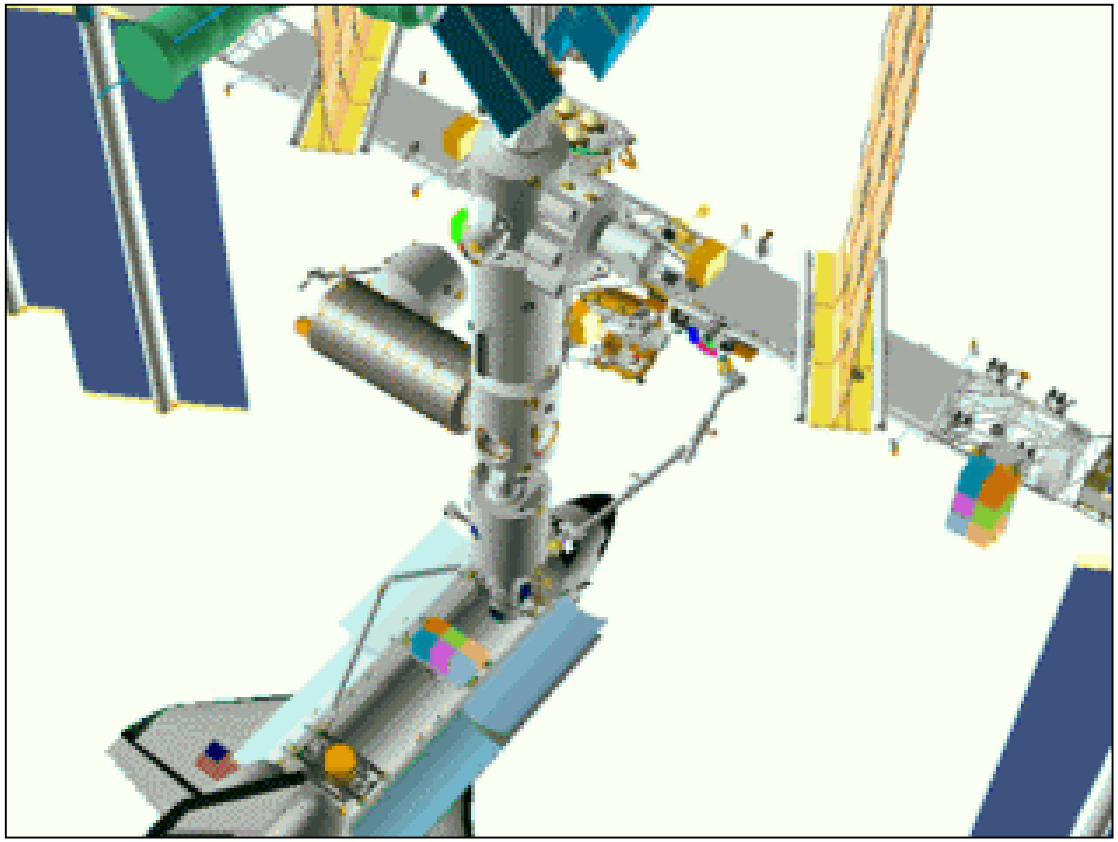
Beta angle	Yaw	Pitch	Roll
+25°	0°	+20°	0°

COLDEST CASE DURING THE HANDOFF

The environment is the worst cold, characterized by:

- Altitude= 270 Nautical miles
- Albedo=20%
- Earth temperature=245.5K
- Solar flux=1300 W/m^2

1. AMS in the STS



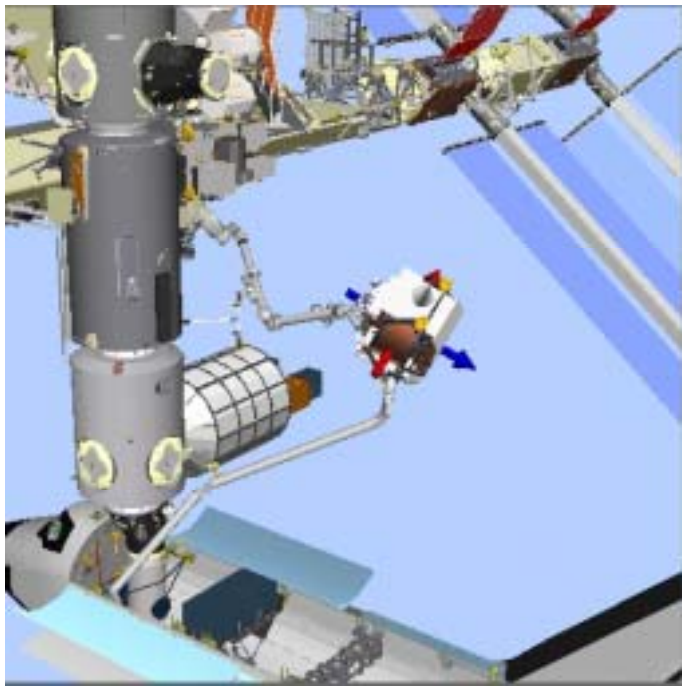
1. AMS in the STS

Power dissipation

input feed	APCU	
max power	2000W	
PDS active bus	B	
PDS	204W	
Nominal users	Cryocooler	480W @ 120V (4A)
	J-CRATE	50W @ 28V (1,8A)
	CAB	30W @ 28V (1A)
POWER HEATERS AVAILABLE		1156,0W
	TRD Gas Box	69W
	Crates RAM radiator	350W
	Crates WAKE radiator	350W
	TTCS boxes	100 W
	HV bricks	60 W
	E crate	10 W
	Tot	**939 W**

CCEB has been considered ON = 80W

2. AMS in the HAND-OFF position



- The precise set of time- dependent positions of AMS during the transfer phase from STS to ISS is not available yet
- The only available information is the intermediate position, when both STS and ISS robotic arms will be attached to AMS
- This is a position where AMS could stay for
  - 1 orbit w/o power
  - 1 orbit with power from ISS arm

2. AMS in the HAND-OFF position

2a). One orbit with AMS completely unpowered

2b). One orbit with the following power applied

input feed	PVGF 1	
max power	2100W	
PDS active bus	A	
PDS	204W	
Nominal users	Cryocooler Heaters	200W @ 120V (0,53Ax4)
	Zenith radiator	4 x 50 W
	J-CRATE	100W @ 28V (3,57AX2)
POWER HEATERS AVAILABLE		1316W
	TRD Gas Box	69W
	Crates RAM radiator	350W
	Crates WAKE radiator	350W
	TTCS boxes	100 W
	CAB	40W
	HV bricks	60 W
	E crate	10 W
	Tot	**979 W**

CCEB has been considered ON = 80W

3. AMS on the ISS

input feed	MAIN	
max power	2100W	
PDS active bus	A	
PDS	204W	
Nominal users	Cryocooler Heaters	200W @ 120V (0,53Ax4)
	Zenith radiator	4 x 50 W
	J-CRATE	100W @ 28V (3,57AX2)
POWER HEATERS AVAILABLE		1316W
	TRD Gas Box	69W
	Crates RAM radiator	350W
	Crates WAKE radiator	350W
	TTCS boxes	100 W
	CAB	40W
	HV bricks	60 W
	E crate	10 W
	Tot	**979 W**

NOT ENOUGH

CCEB has been considered ON = 80W

(same as before)

Transfer Analysis Results

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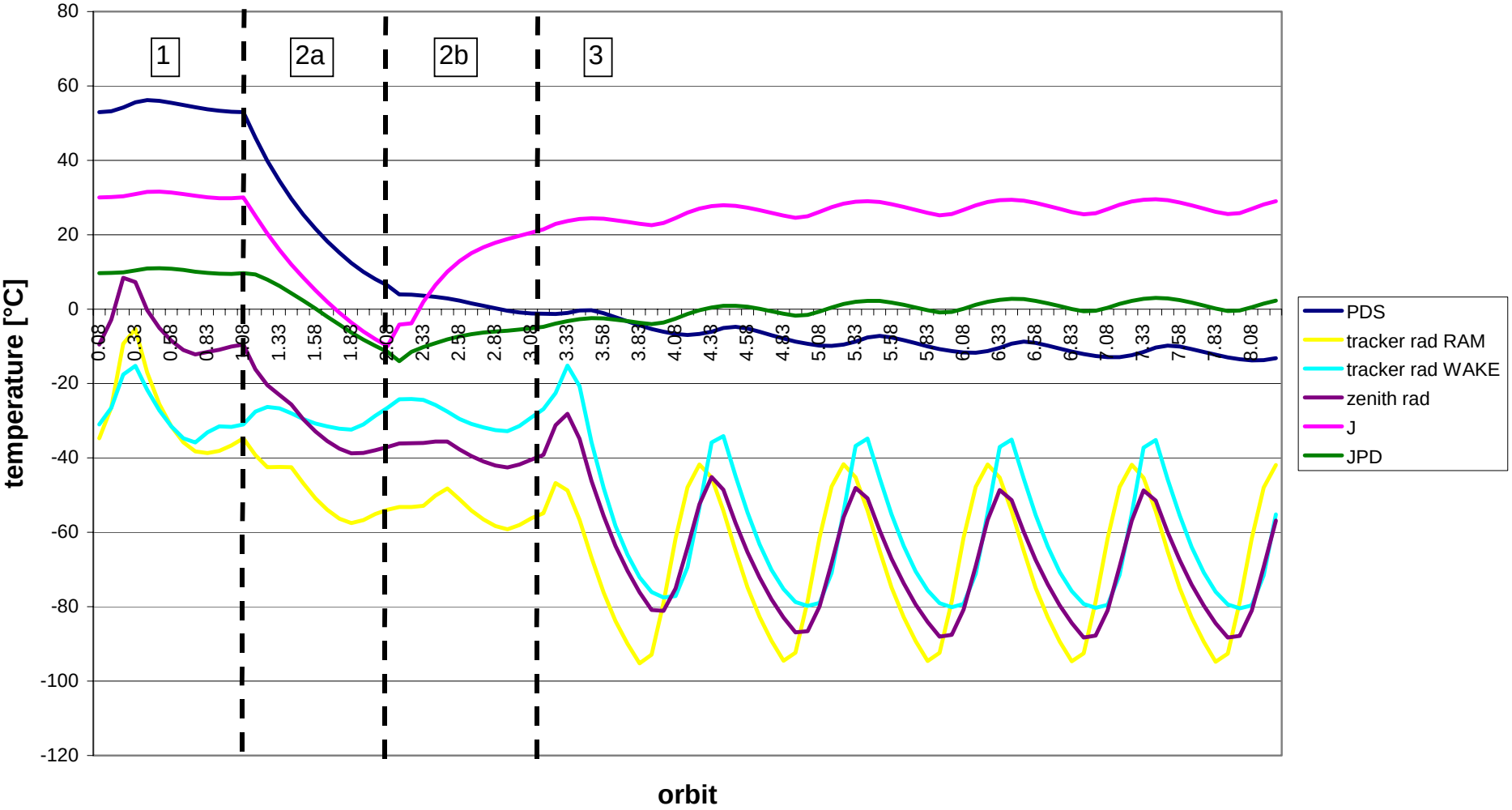

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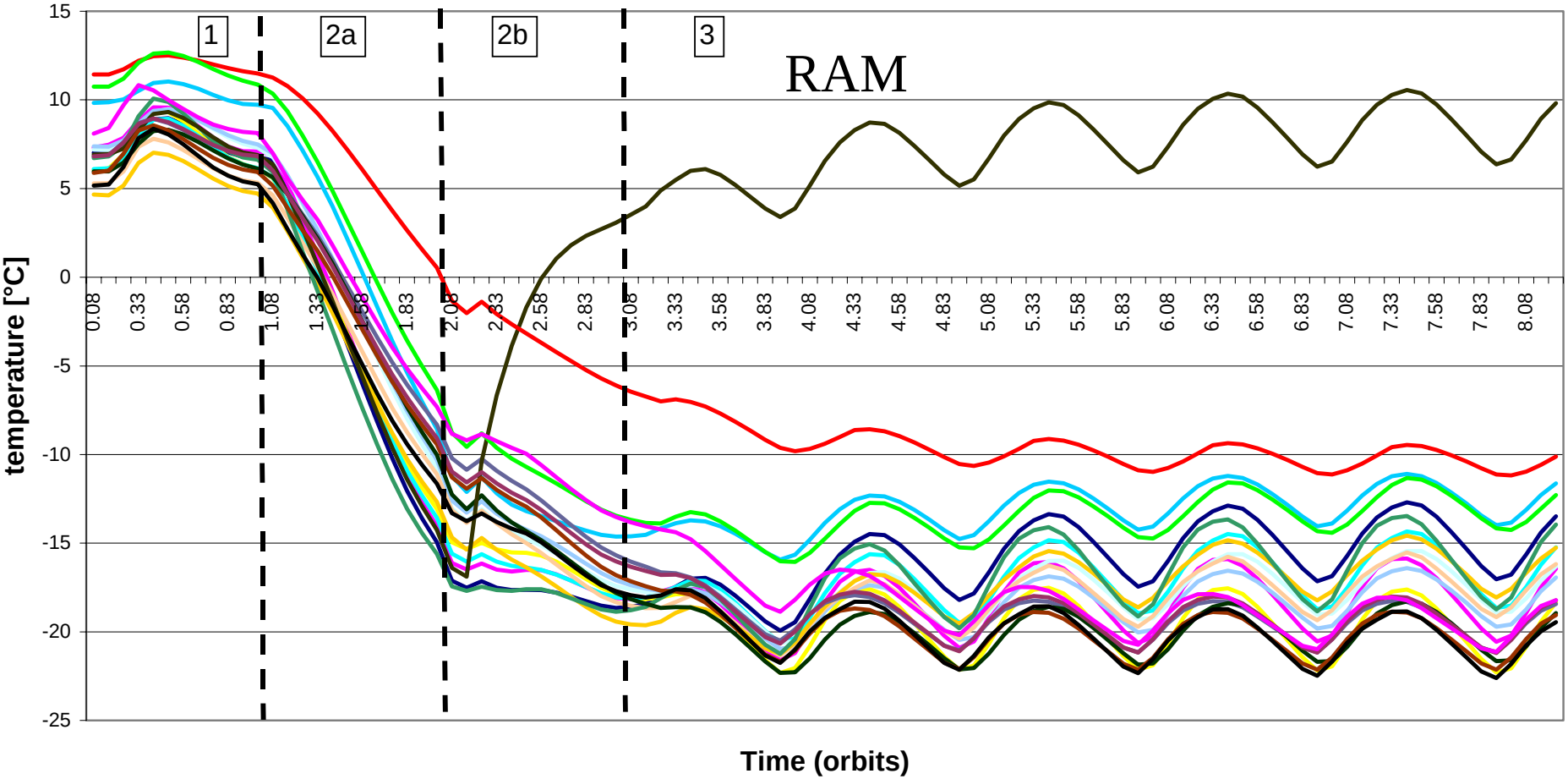

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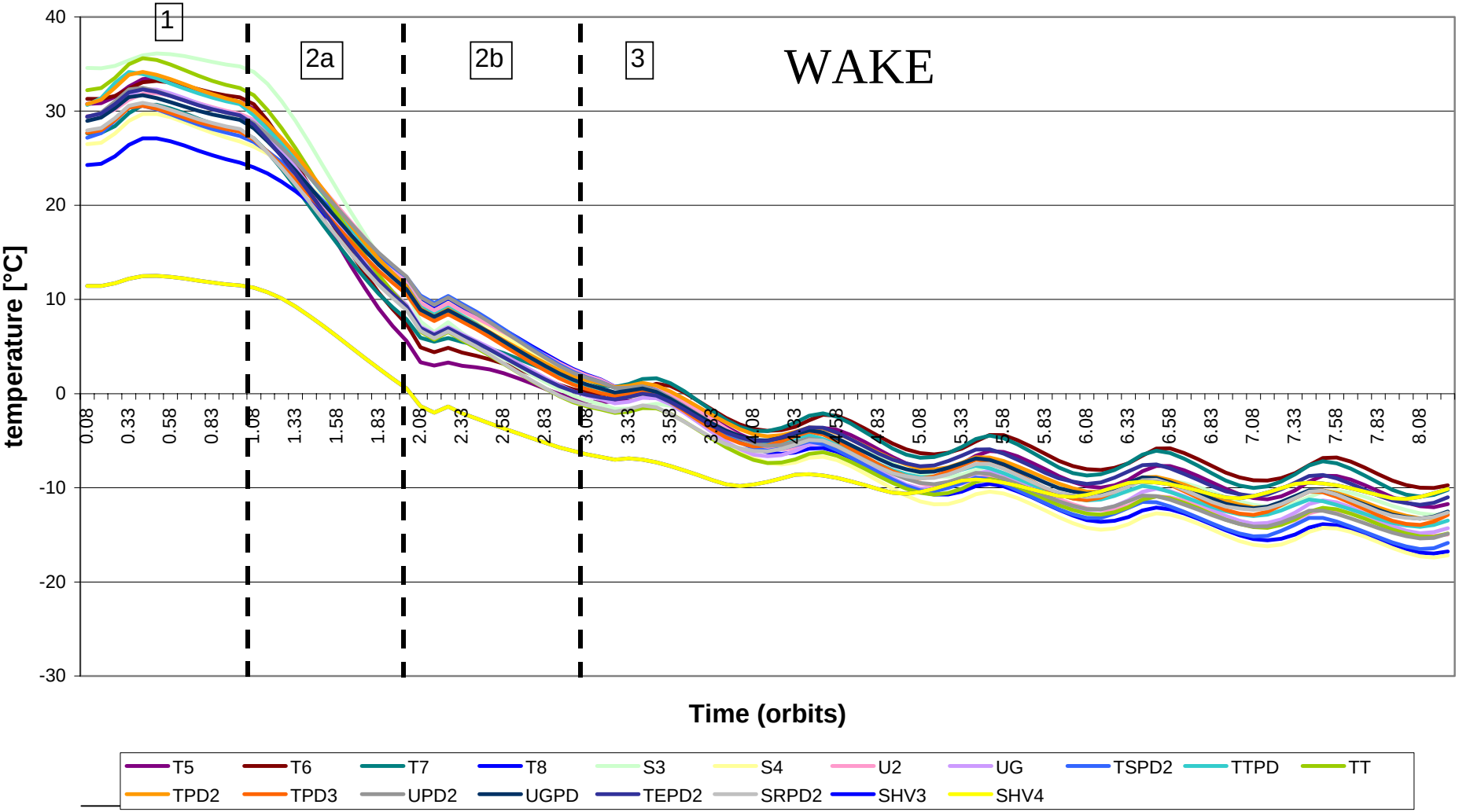

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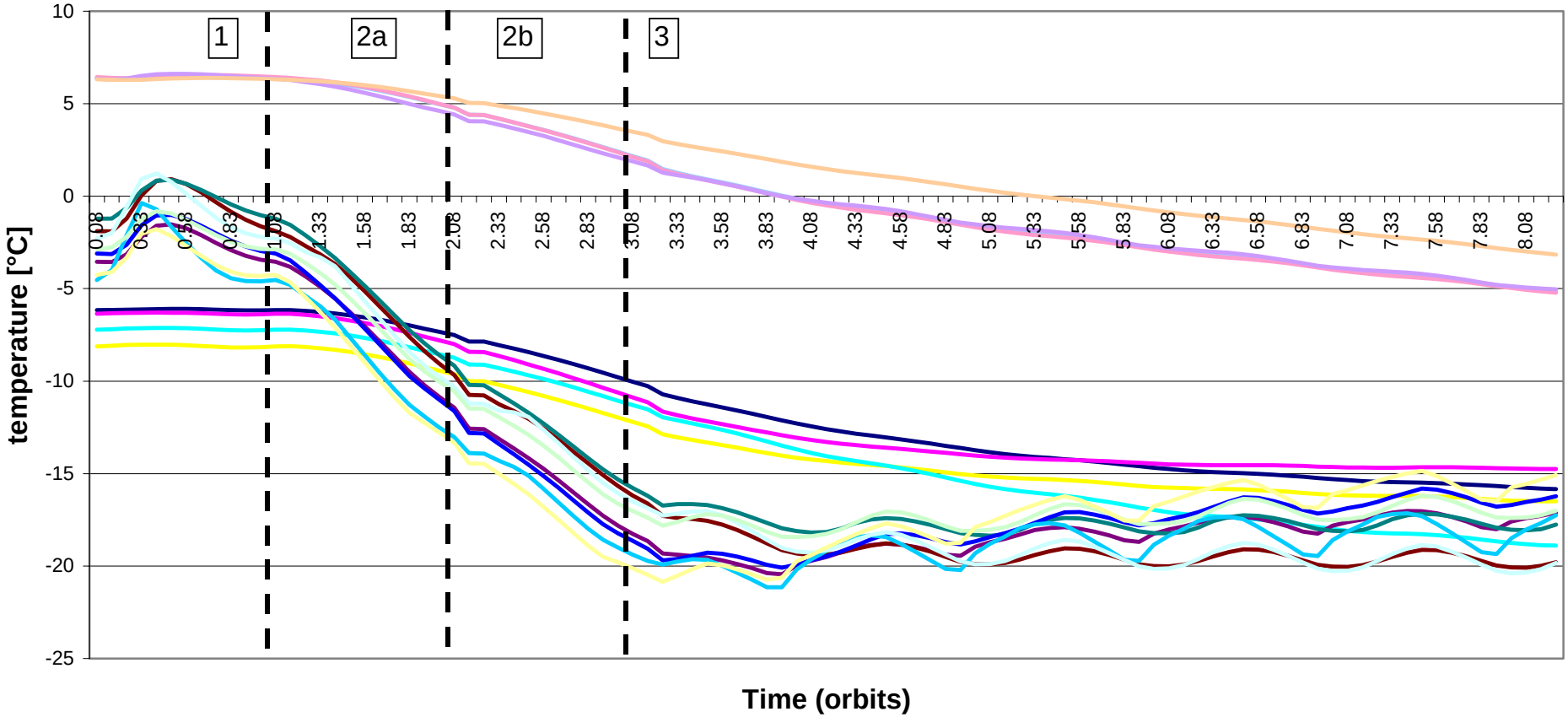

Why do we need heaters?

1. To keep AMS above survival conditions during transfer from STS to ISS
2. **To warm up whatever needs to be warmed up during cold conditions to keep the temperature higher than the minimum operative/non operative limit**
3. To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)

AMS is operating under extreme cold case:

Item	Power (W)	Calculated by	Orbital case (β, YPR)
TRD Gas Box	69	LMSO	0 –15 +15 –15
HV bricks	60W (TBC)	CGS	
Cryocoolers	50 each = 200W	OHB	+75 –15 +15 +15
RICH	TBD (depending on ongoing tests)	CGS	TBD
TTCB P or S	50W + 50W	Proposed by CGS	
TOTAL	**429W**		

Why do we need heaters?

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3. **To activate sequentially AMS after a period of outage of power (e.g. de-freeze fluidic parts before restoring operative conditions)**

AMS-02 re-activation after Power outage

Extreme cold case for WAKE(*)

Beta angle	Yaw	Pitch	Roll
+75°	-15°	-20°	+15°

The environment is characterized by:

- Altitude= 270 Nautical miles
- Albedo=20%
- Earth temperature=245.5K
- Solar flux=1300 W/m^2

(*): PDS radiator

Step sequence

1. AMS is operating
2. AMS is suddenly shut down
3. FIRST TASK: define how long we can remain un-powered ?
4. As soon as one of the sub-detectors/sub-system is going under the minimum storage temperature we have to restore power to make the activation sequence start. NO TEMPERATURE MONITORING AT ALL.
5. PDS minimum switch-on conditions have to be restored
6. PDS HEATERS ON (230W)
7. As soon as T=-25°C is reached at PDS TRP, PDS is turned ON and PDS heaters are switched OFF by a thermal interlock device (TBD)
8. STILL NO TEMPERATURE MONITORING AT ALL

Step sequence

9. If PDS is ON we can turn ON all the heaters we need: which ones ?
   - ✓ MAIN RADIATORS
   - ✓ CAB + TRDGB
   - ✓ TTCB
   - ✓ HV BRICKS + E-CRATE
10. We can NOT turn ON heaters on :
   - ✓ CRYO-BODY ----- zenith radiators could be frozen
11. We have both the choices (ON/OFF) for the heaters on :
   - ✓ ZENITH RADIATORS
   - ✓ TRACKER RADIATORS

12. Finally thanks to the heaters on the main wake radiators J+JPD boxes reach their minimum switch-on temperature and the JPD can be powered up. This is done controlling the power input line from PDS in a thermostatic way.
13. As soon as J-crate is operating we can start (via JMDC) to monitor temperatures via **GTSN**
14. **DTS MONITORING AVAILABLE**
15. **LOW TEMPERATURE MONITORING (zenith and tracker radiators) DONE IN CCEB AND TT CRATE NOT AVAILABLE**
16. CCEB and TT Crate ON as soon as they reach switch on temperature
17. Readout of zenith and tracker temperature available
18. Unfrozen heaters ON on zenith/tracker
19. Substitution heaters ON on cryos when zenith is unfrozen

20. LHP starts working
21. Cryo reach minimum switch on
22. Cryocoolers ON

PDS switch on temp = -20°C

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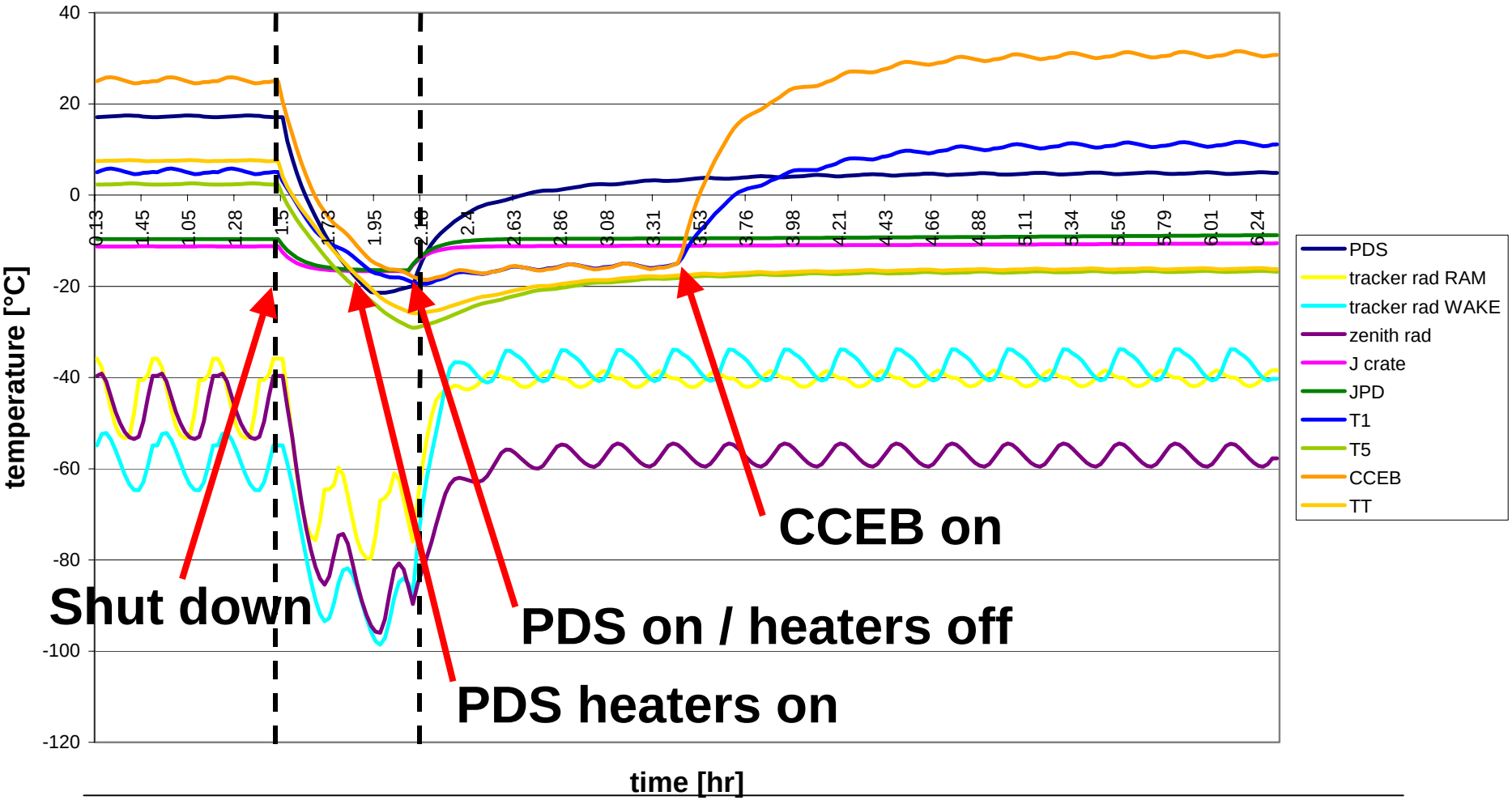
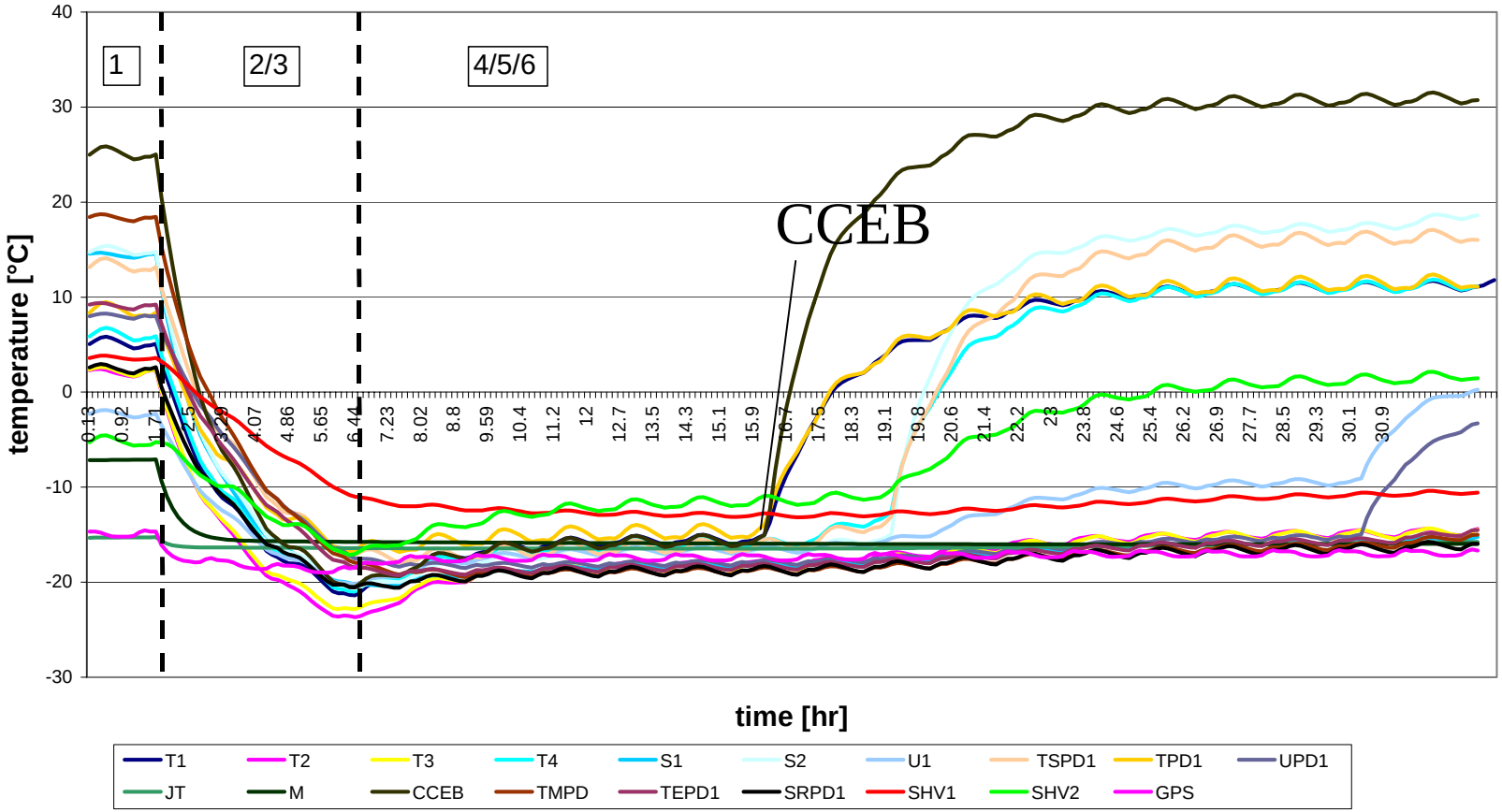


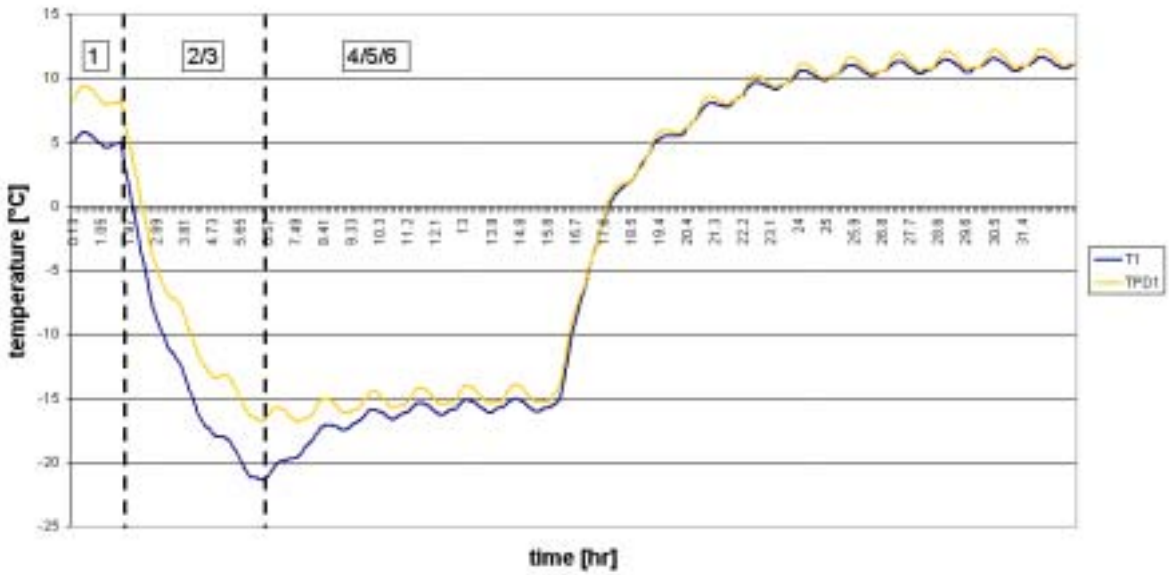
Crates on RAM radiator

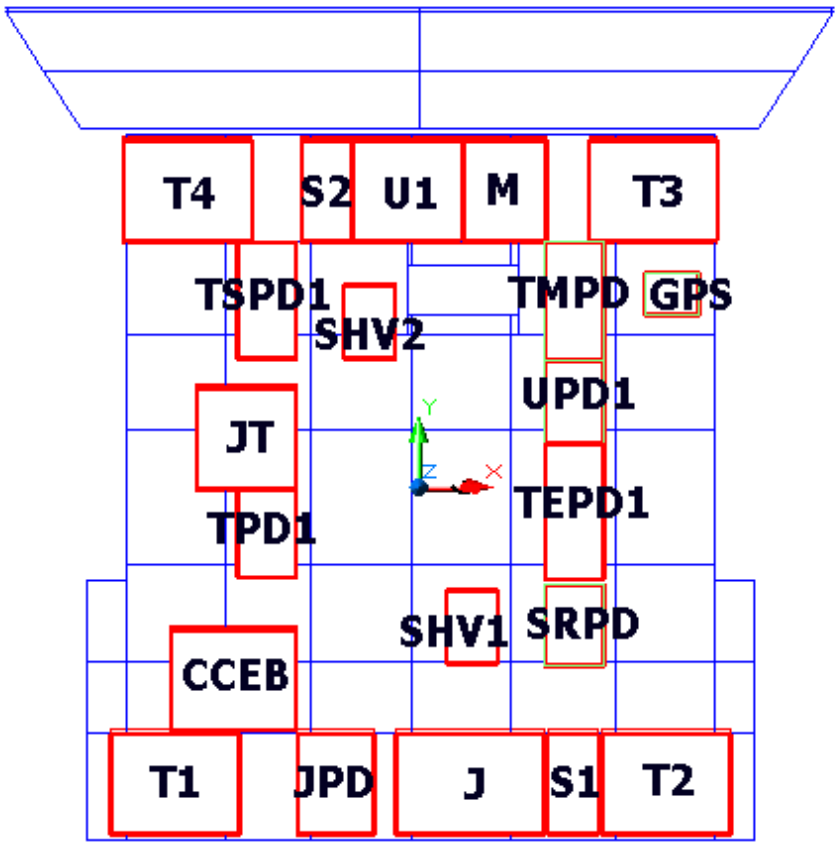


	@-15°C	ON
U1	18 hr 40min	28 hr 47min
UPD1	28 hr 47min	

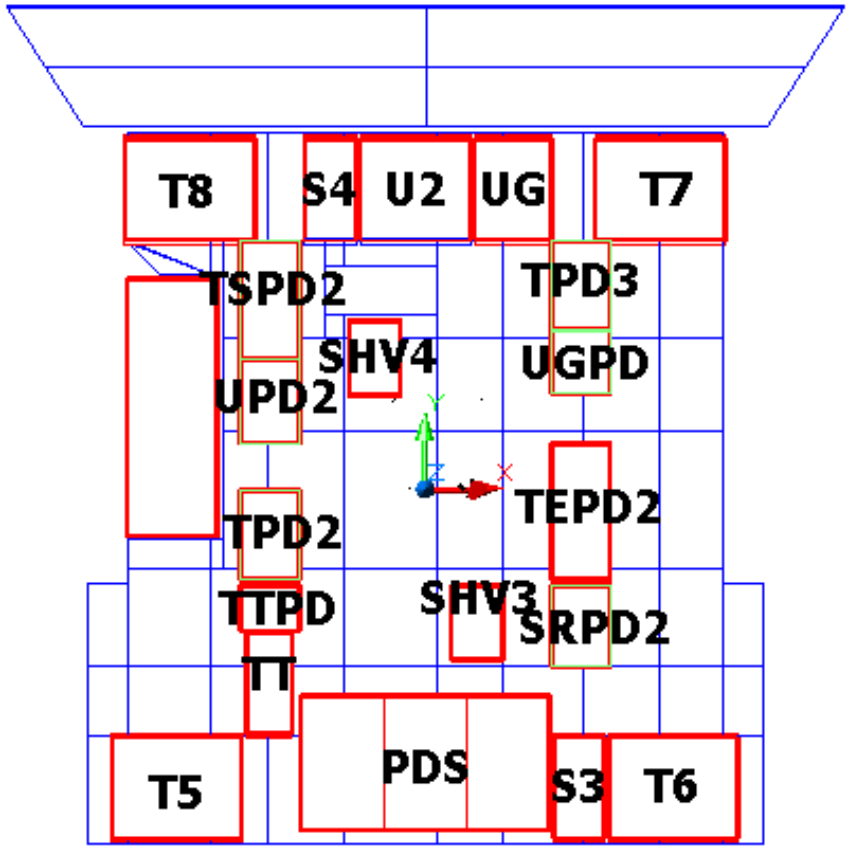
	@-15°C	ON
T1	14 hr 38min	14 hr 38min
TPD1	8 hr 8min	

	@-15°C	ON
T4	16 hr 18min	17 hr 37min
S2	17 hr 37min	
TSPD1	16 hr 18min	
SHV2	6 hr 27 min	



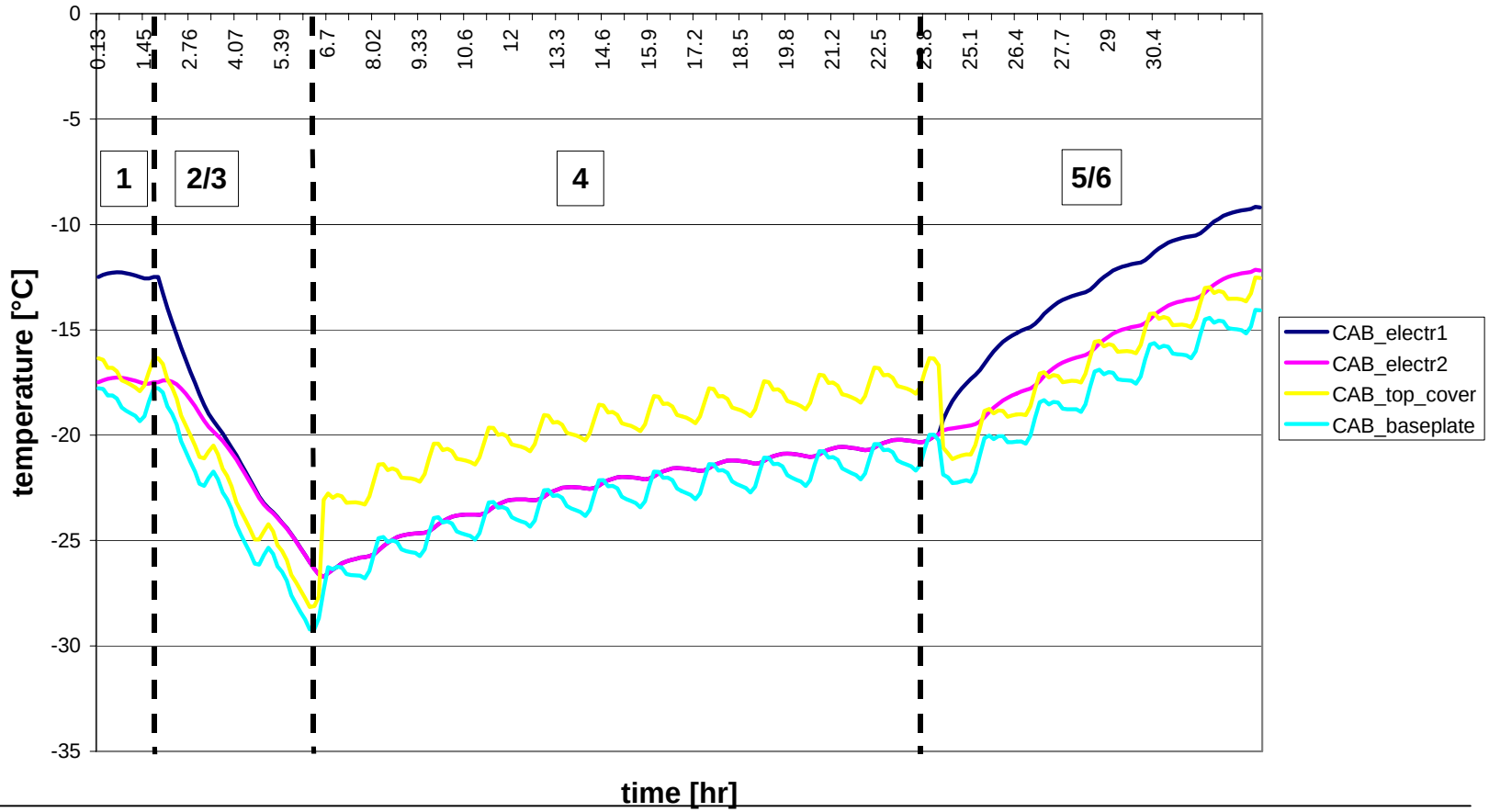

T4
S2
U1
M
T3
TSPD1
SHV2
TMPD
GPS
UPD1
JT
TEPD1
TPD1
SHV1
SRPD
CCEB
T1
JPD
J
S1
T2

RAM


T8
S4
U2
UG
T7
TSPD2
TPD3
SHV4
UGPD
UPD2
TEPD2
TPD2
TTPD
SHV3
SRPD2
TT
T5
PDS
S3
T6

WAKE

CAB


0
-5
-10
-15
-20
-25
-30
-35
temperature [°C]
0.13
1.45
2.76
4.07
5.39
6.7
8.02
9.33
10.6
12
13.3
14.6
15.9
17.2
18.5
19.8
21.2
22.5
23.8
25.1
26.4
27.7
29
30.4
1
2/3
4
5/6
time [hr]
CAB_electr1
CAB_electr2
CAB_top_cover
CAB_baseplate

Conclusions

- A preliminary heater power sizing has been performed at system level
- Confirmation shall be provided by sub-system according to their detailed thermal analysis
- Power budget has to be checked